



State of LIGO

Gary Sanders
LIGO/Caltech
LSC Meeting, LLO
March 16, 2004



A 10 Year Anniversary

- LIGO's "near death" experience of early 1994
 - » LIGO's second chance
- What was our hoped for outcome?
 - » The NSB would start LIGO again
 - » We would build it and not get into too much trouble along the way
 - » It would work pretty much the way it was designed
 - » Nature would be **very very** kind
 - » We would live to upgrade it
- What has happened?
 - » 3 out 5 so far, not bad
 - » >500 members of the LSC (so LIGO Lab a less important idea)
 - » LIGO has become a positive example at NSF and many other venues where big science is scrutinized
- **LIGO is in a remarkable state, not envisioned in 1994**



From a site visit of the National Science Board

Building a Scientific Facility that Integrates Research and Education

Gary H Sanders

NSB Site Visit

LIGO Livingston Observatory

February 4, 2004

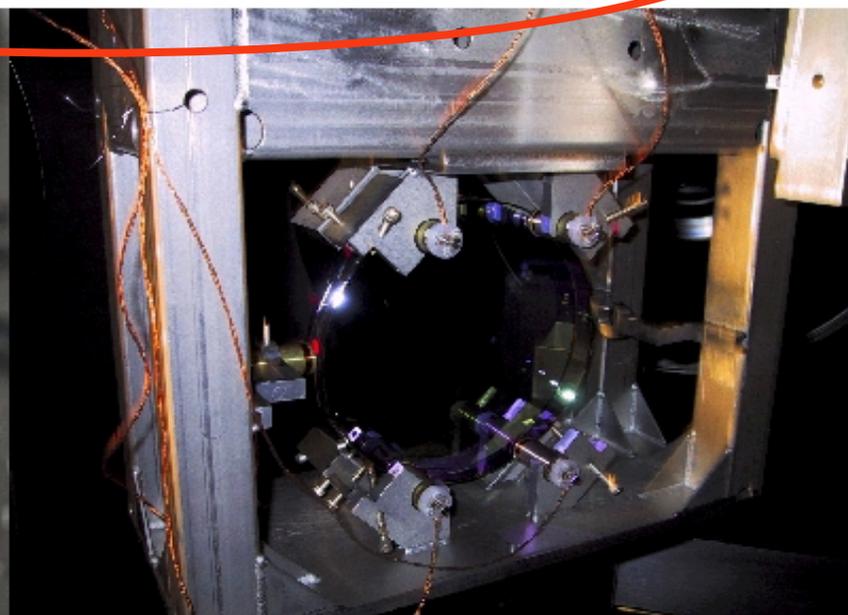
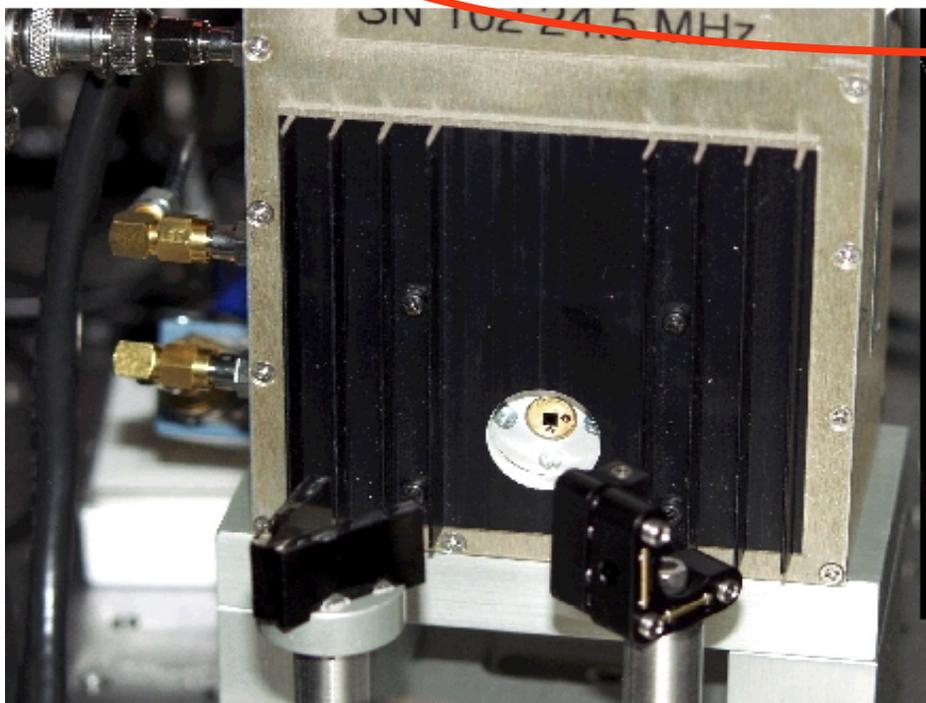


Notable activities by year

Year	Facility	Detector	Broader Impacts
1996	civil construction	design	site based planning
1997	vacuum system	fabrication starts	LHO teacher workshop
1998	facilities ready	fabrication	LHO REU
1999	completion	installation in vacuum	LLO REU, LHO SST
2000	early operation	installation and subsystem commissioning	
2001	early operation	full commissioning, coincident operation	LLO RET, LHO RET
2002	operation	sensitivity studies, science run 1 (S1)	LHO LEN formed
2003		S2 and S3, first results	LLO LEN, LLO SUBR, LABoR, Exploratorium
2004		science running, reach design sensitivity	ISE, IPSE, outreach center development
2005-7		complete 1 year run	LSC coordination, NSF video
2008+	Exploit terrestrial limit	Advanced LIGO proposed	



LIGO- I: Breaking the Sensitivity Barrier



March 2nd, 2004

Rana Adhikari

MIT

LIGO-G040XXX-00-D

LIGO-G040130-00-M



OUTLINE

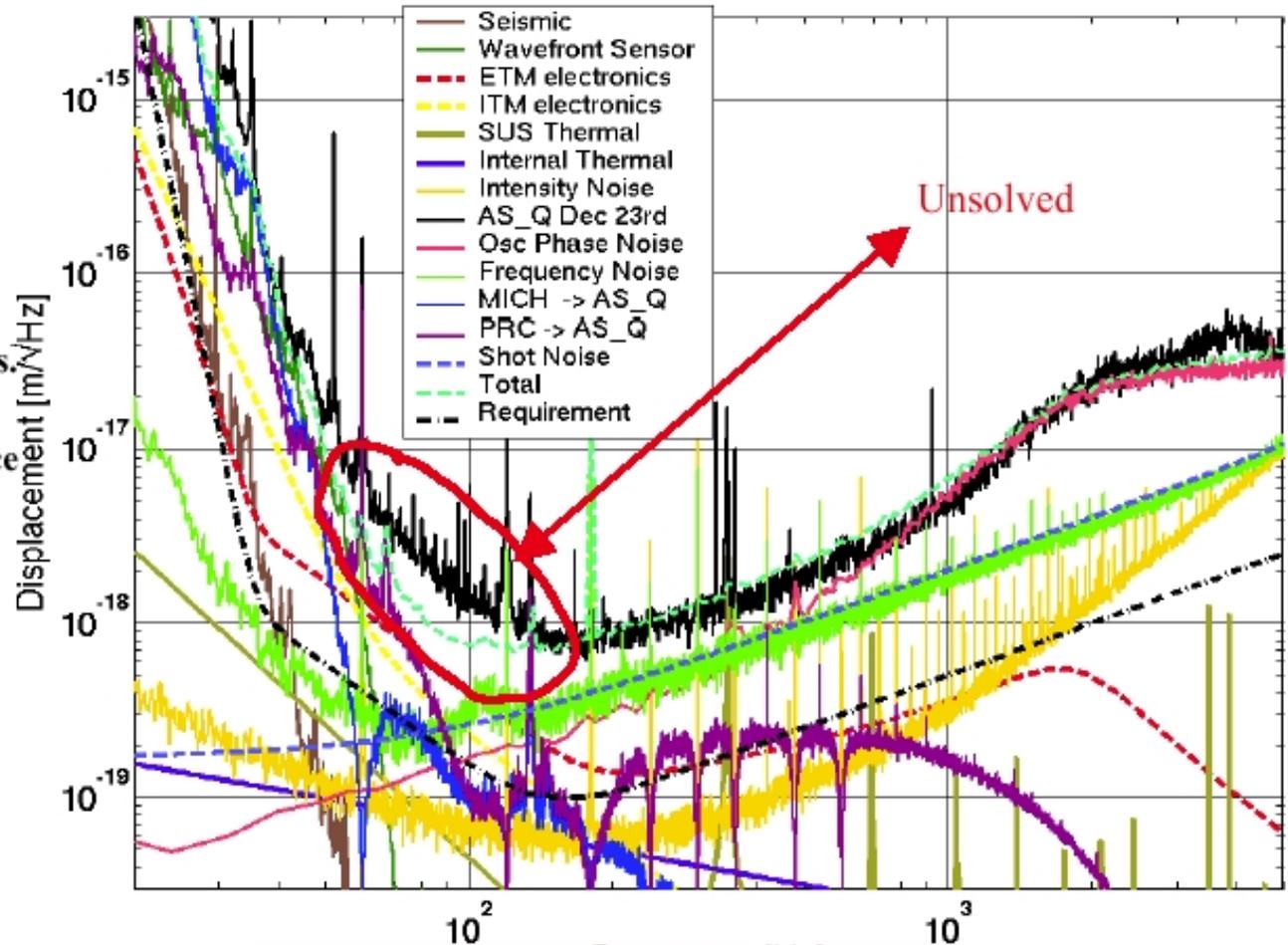
- What is the noise in the interferometers now?
- *Where does the SRD Curve come from?*
- What we know about the 'fundamental' noises.
- **Can we ever reach the SRD ?**
- What do we do about it?

From Rana's talk



The Noise in Livingston

- ~10X higher than design...
- ~10⁵ X lower than a few years ago.
- Most of the noise is explained by the models.
- Plans are in place to reduce each noise source above SRD.



LIGO-G040XXX-00-D

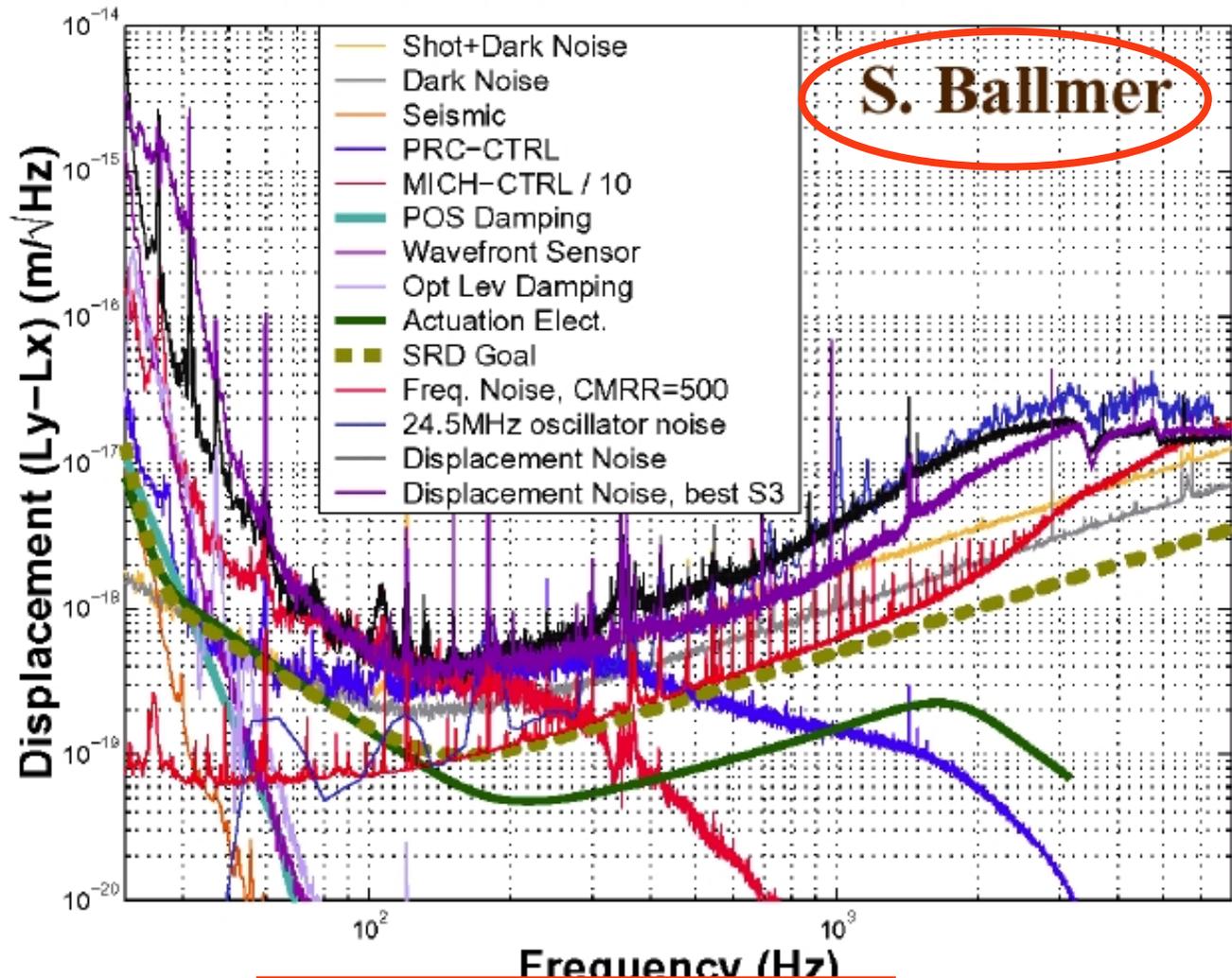
From Rana's talk

LIGO-G040130-00-M



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H1 Noise Sources: 23 Feb 2004



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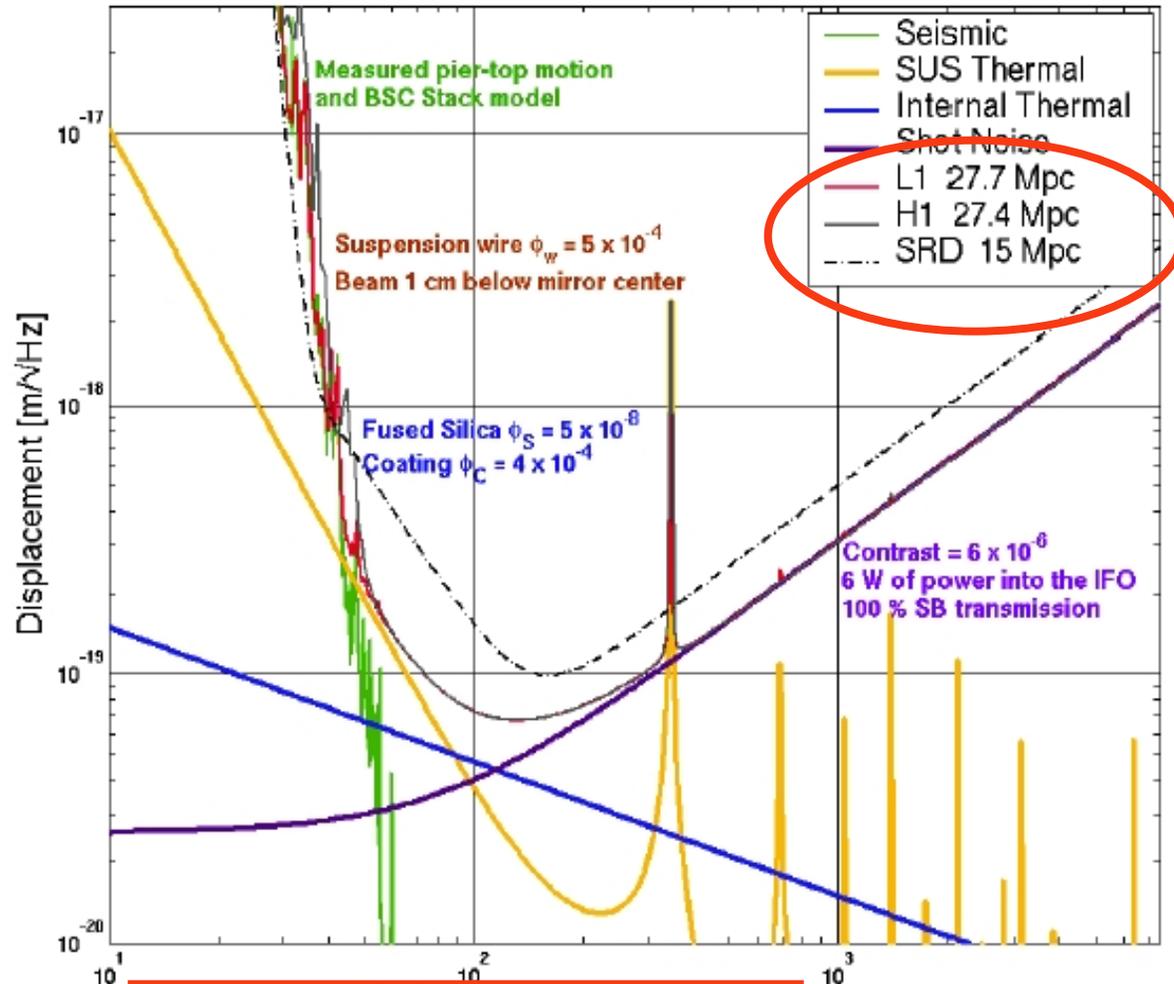
From Rana's talk

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The Noise Spectrum

- ➔ Identical Thermal Noise assumed for both IFOs
- ➔ Slightly more seismic noise in Hanford than in Livingston !
- ➔ Nice improvement in NS/NS Inspiral Range.
- ➔ S4? S5?



LIGO-G040XXX-00-D

From Rana's talk

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Summary

- ✦ *What is the noise in the interferometers now?*
 - **Mostly known. Not unfixable.**
- ✦ *Where does the SRD Curve come from?*
 - **Conservative estimates that look pretty close.**
- ✦ *What do we know about the 'fundamental' noises?*
 - **The Seismic may be a little high, the others look good.**
- ✦ *Can we ever reach the SRD ?*
 - **Yes, but that's easy.**
- ✦ *What do we do about it?*
 - **Continue as planned, re-evaluate technical sources**

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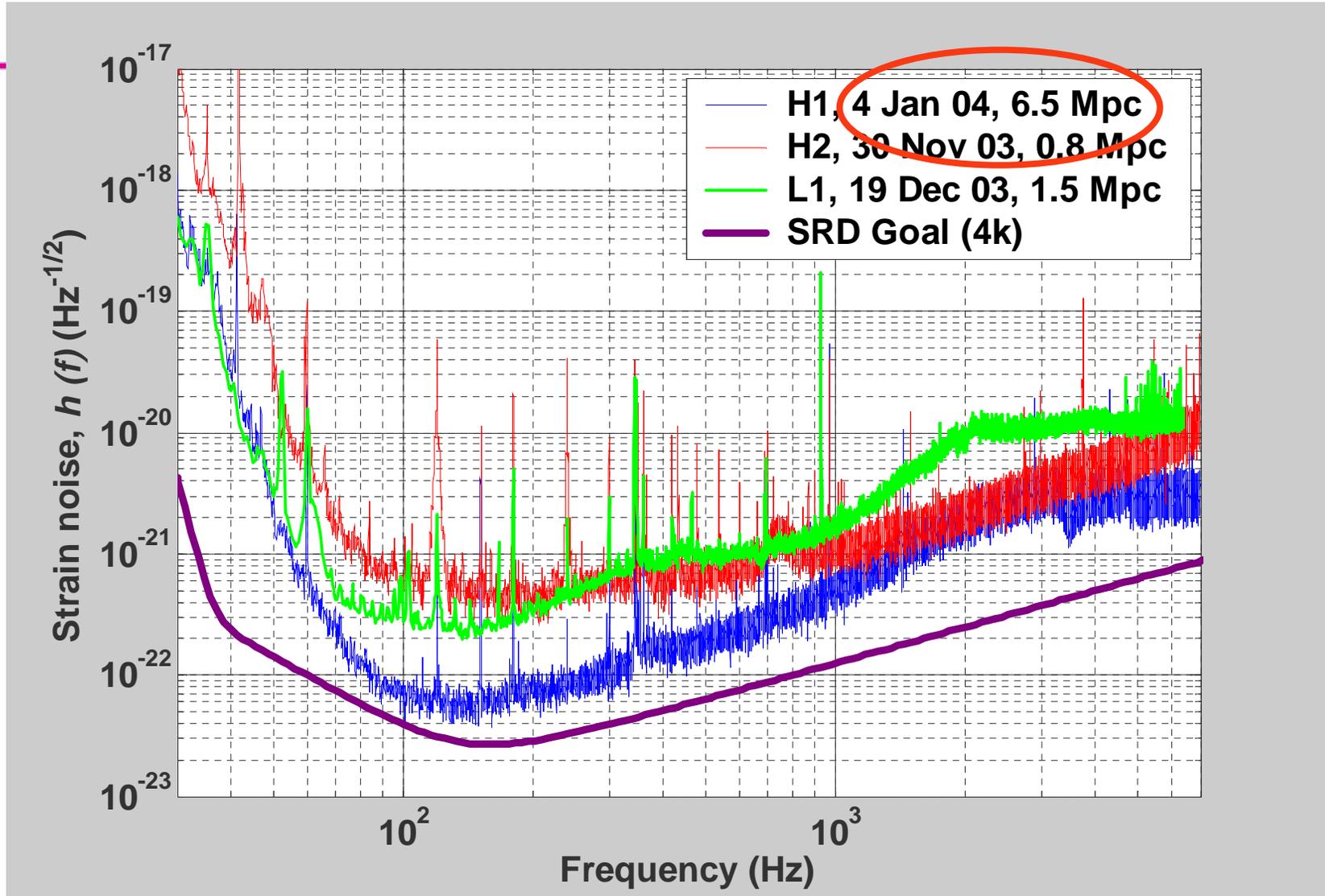
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From Rana's talk

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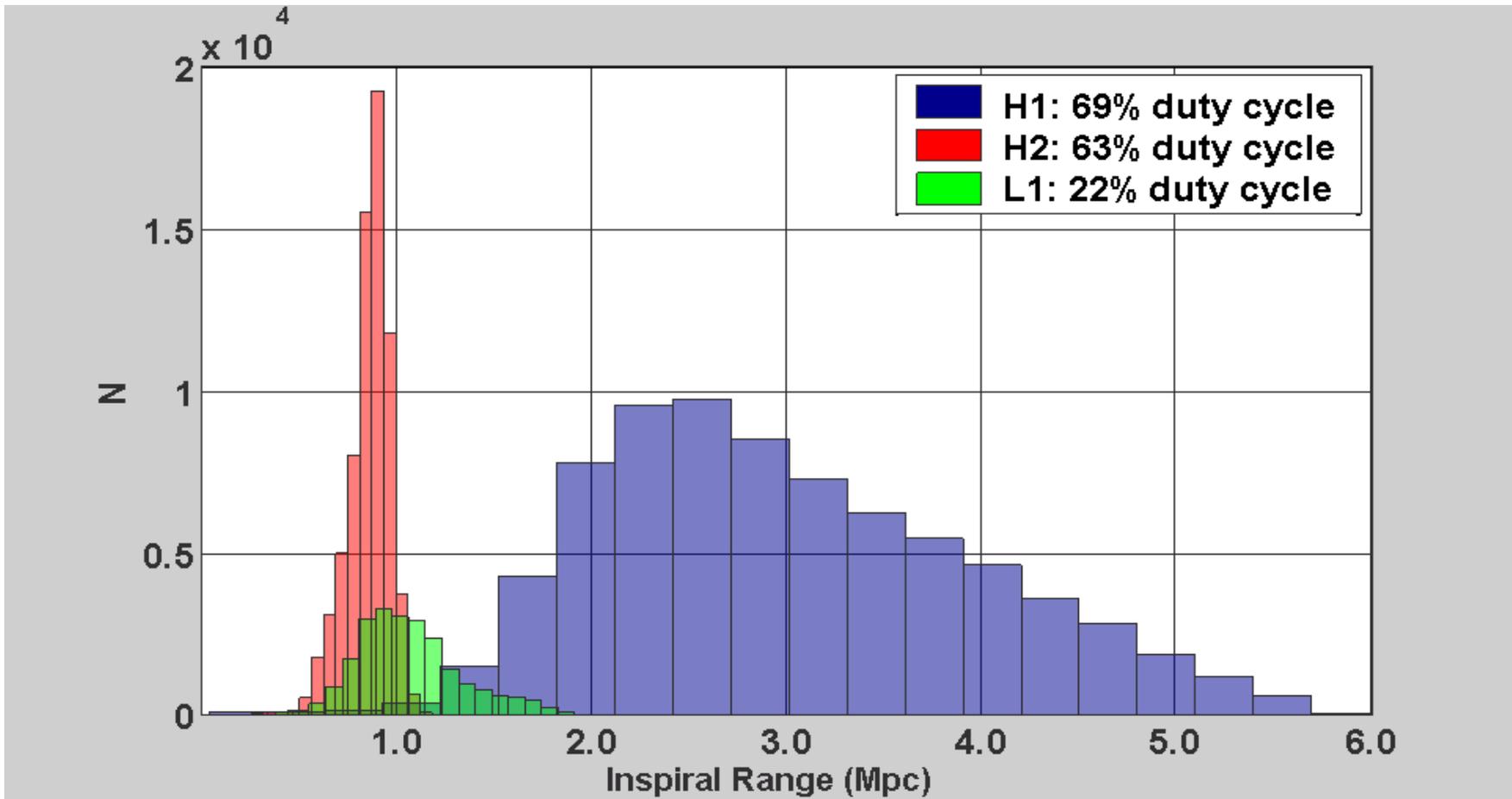
S3: peak sensitivities





“Availability”

S3: reliability & stability





Major Goals and Tasks After S3

- **Sensitivity**

- » Operate at high power: achieve designed optical gain
 - Laser
 - Thermal compensation system (TCS)
 - Output mode cleaner (OMC) (thanks to GEO for the loan)
- » Manage noise in auxiliary degrees-of-freedom
- » Finish acoustic mitigation
- » Clean up electronics: RFI mitigation

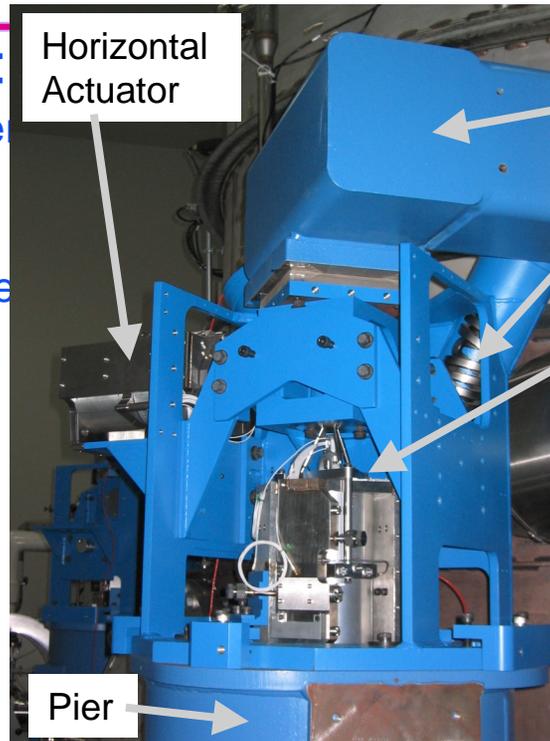
- **Reliability & Stability**

- » Seismic retrofit at LLO: HEPI
- » Auto-alignment system: all degrees-of-freedom, at full bandwidth
- » Address causes of lock-loss



Seismic Isolation: Hydraulic External Pre-Isolation (HEPI)

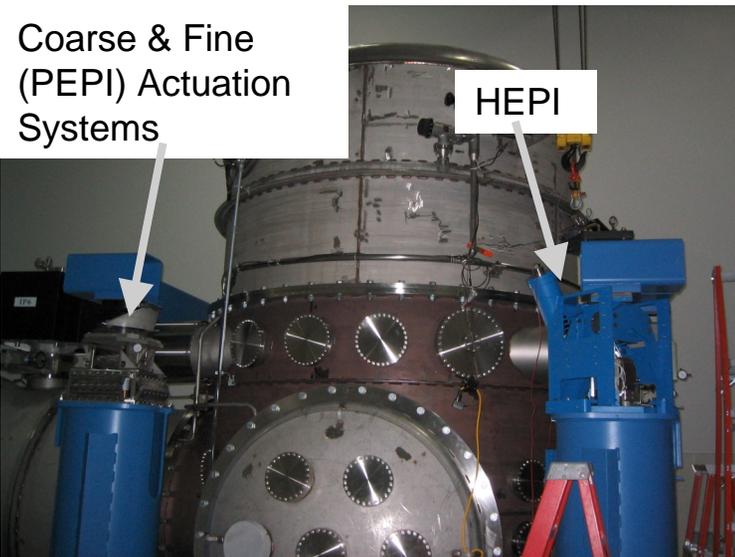
- LASTI Testing/development:
 - » Working on a LASTI HAM chamber
 - » HAM stiffening beam found unnecessary
 - » Verified SOS are OK on HAM table during excitation for system identification
 - » Adapted GDS for HEPI Sys ID



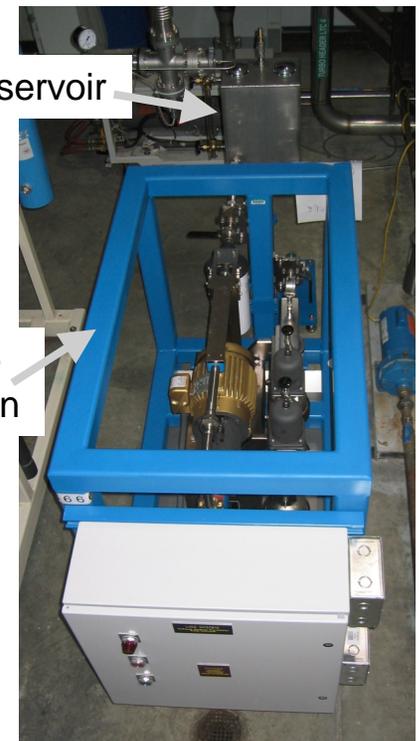
Crossbeam

Helical Spring (1 of 2)

Vertical Actuator

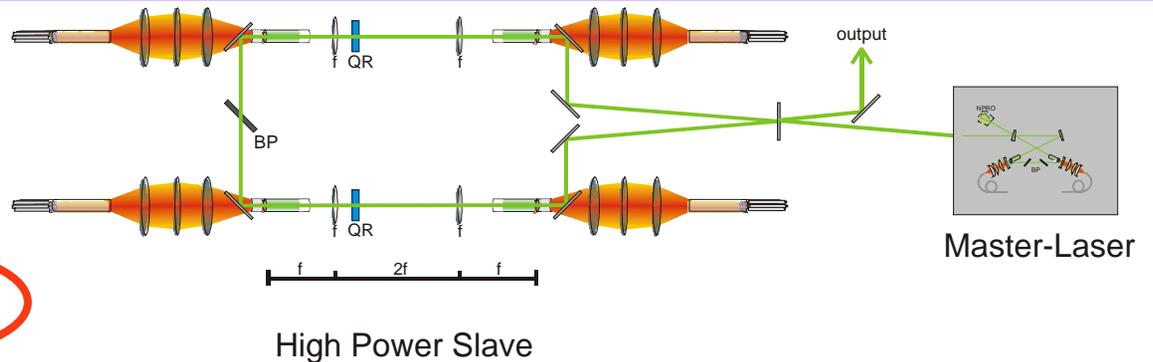


- Production:
 - » Part fabrication nearly completed
 - » Being assembled & installed at LLO X-end now



Advanced LIGO R&D

- Pre-Stabilized Laser (PSL)
 - » LZH/MPQ optimizing birefringence compensation
 - » Demonstrated >165 W



High Resolution Image of Scatter from the ITMx,2k HR Coating

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- Core Optics Components (COC)
 - » Substrate downselect June 2004
 - » LMA-Lyon confirmed high ~50 ppm/cm average absorption in another two large Crystal Systems
 - » Coating program with LMA-Lyon and CSIRO is underway
 - » Coating scatter loss is a significant issue under investigation



Advanced LIGO R&D

- Seismic Isolation (SEI)

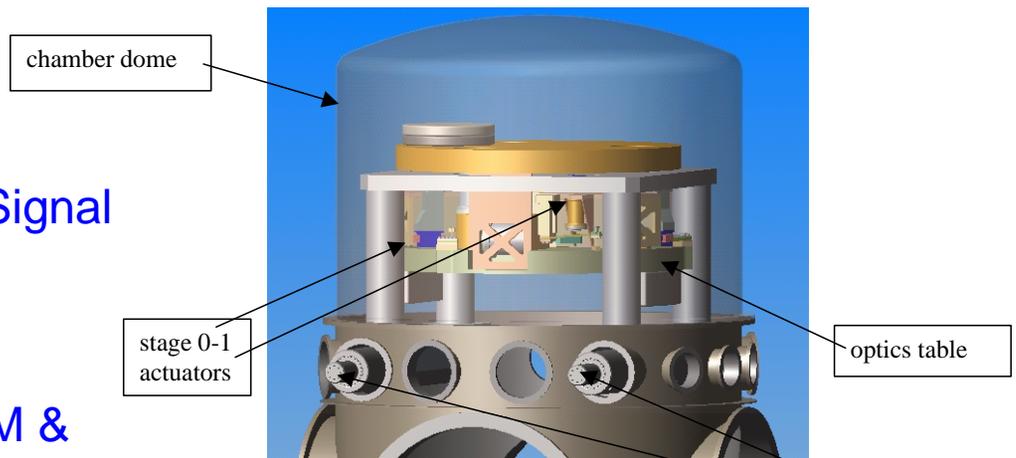
- » ETF testing continues (sensor characterization, electronics noise reduction, transfer function measurements, controls, ...)
- » HAM & BSC Prototype mechanical design
 - Difficult to meet stiffness requirements and extremes in payload mass properties
 - Design review early/mid April

- Interferometer Sensing & Control (ISC)

- 40m LAB

- » Robustly locking the Fabry-Perot Michelson interferometer
- » Vented & installed the Power & Signal Recycling Mirrors
- » Mode Cleaner and Fabry-Perot Michelson have locked again! (with intentionally mis-aligned PRM & SRM)

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Commissioning and the Next Science Running

- Commissioning Goals for discussion at this meeting
 - » H1, H2
 - Reach SRD performance in substantial parts of the spectrum for H1
 - Get H2 as close to this as possible
 - Availability should be as it was in S3 (~70%)
 - » L1
 - HEPI to be installed and commissioned to isolation goal
 - L1 sensitivity as close as possible to H1, H2
 - L1 availability equal to H1 in S3 (~70%)
- Drop scimon staffing for S4 to one person per 24 hours, on call
- Assume next running schedule is an S4 run, a commissioning gap, and a long S5 run



S4, the Gap, S5

- S4 has much improved triple coincidence availability and data quality
 - » L1 runs 24/7
 - » L1 as sensitive as possible, approaching H1, H2
 - » S4 begins 8 am Nov 1, ends before Xmas (8 am Dec 20) if all goes well
- “The Gap”
 - » January - February - March 2005
 - » Consolidate SRD sensitivity in L1, H1, H2
 - » Address remaining availability improvement tasks to substantially reach SRD availability goal
 - » Analyze S4 data to inform S5 online analysis
- S5 begins 8 am April 1, for at least 6 months



S5, ...S6

- S5 duration 6 months, running very close to SRD sensitivity and availability
- Maintenance periods to total < 10% of that time
 - » prescheduled with emphasis on keeping as many IFOs running as possible
 - » start with strawman scheduled maintenance shutdowns starting on some Monday mornings
 - » Modify this dynamically and carefully as insight is gained
- Inclusive OR
 - » Not scheduled in advance but inserted dynamically as interventions are collected
 - » Add some regular maintenance as experience dictates
- Shutdown for 1 month at end of S5 for maintenance and IFO studies
- Initiate S6 for another 6 month run following pattern above
- Data analysis challenged to keep up



Summary

- The LIGO community has accomplished a great deal in the past decade
- LIGO is entering a new phase of Laboratory/LSC governance, integrating most activities and responsibilities
- Initial LIGO interferometers are close enough to goals that design appears to be sound
- Science is appearing at an accelerating pace
- A new partnership in Louisiana education and outreach may be approved very soon
- Advanced LIGO is under active consideration by the National Science Board
- International partnerships are strengthening